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An Introduction to Human Factors and Combat Models

by

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This thesis discusses the incorporation of human factors into combat models. First, an historical perspective to determine the significant human factors reveals that human factors fall into two categories based upon when they affect man the most: before/after battle and during battle. Next, combat models are reviewed. Various purposes and model structures are discussed. Finally, incorporating human factors into combat models is discussed. It is argued that the model and the human factors must simultaneously be considered, for the selection of one influences the selection of the other. The structure and purpose of the model may limit which human factors can be considered. Analysis of the model's sensitivity to human factor representations will indicate which human factors are significant in that model. Furthermore, empirical data are lacking and not all human factors are mathematically representable at the current time. Some human factors, such as decision making, may be included using artificial intelligence techniques until data are obtained, if possible. When models and human factors are combined, the model must still be usable and understandable. The conclusion is that human factors should be incorporated into combat models, step by step, as the data and mathematical representations are developed.

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An Introduction to Human Factors and Combat Models

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ABSTRACT

This thesis discusses the incorporation of human factors into combat models. First, an historical perspective to determine the significant human factors of combat reveals that human factors fall into two categories based upon when they affect man the most: before/after the battle, and during the battle. Next, combat models are reviewed. Various purposes and model structures are discussed. Finally, incorporating human factors into combat models is discussed.

It is argued that the model and the human factors must simultaneously be considered, for the selection of one influences the selection of the other. The structure and purpose of the model may limit which human factors can be considered. Analysis of the model's sensitivity to human factor representations will indicate which human factors are significant in that model.

Furthermore, empirical data are lacking and not all human factors are mathematically representable at the current time. Some human factors, such as decision making, may be included using artificial intelligence techniques until data are obtained, if possible. When models and human factors are combined, the model must still be usable and understandable. The conclusion is that human factors should be incorporated into combat models, step by step, as the data and mathematical representations are developed.

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I. INTRODUCTION

War. Man has participated in war throughout his existence here on this planet; from the Battle of Jericho around 1200 B.C., to the recent war between the Soviet backed Afghan army and the Afghan **mudjahadeen**, or "freedom fighters". In just the 20th century alone, there have been more than 200 wars, 36 of these active at the end of 1986, pitting five and a half million soldiers from one quarter of the earths nations against each other (Stockholm International Peace Research Institute,pg.,xxvi). It is not surprising, then, that man has thought about war and tried to understand it. Well known, early writings date back to Sun Tzu's <u>The Art of War</u>, circa 400 B.C., and range all the way to the present.

These writers have tried to understand the nature of war and battle. One of the most influential writers of the nineteenth century, Carl von Clausewitz, said that war was a remarkable trinity

> ...composed of primordial violence, hatred, and enmity, which are to be regarded as a blind natural force; of the play of chance and probability within which the creative spirit is free to roam; and of its element of subordination as an instrument of policy, which makes it subject to reason alone. (Howard,pg.,73)

He stated succinctly that " war is the trial of moral (the will) and physical forces by means of the latter"

(Howard,pg.,26) and he concluded that " moral factors, then, were the ultimate determinants in war...." (Howard,pg.,29)

The importance of moral factors, or human factors as they are commonly called today, was reaffirmed in the late 20th century when Dupuy and Hammerman (pg.,14) concluded that "human factors were found to be the major determinants of the outcome of battles fought during these (the 1973 Arab-Israeli) wars."

One modern way of thinking about and trying to understand war is exemplified in the methodology of constructing and using combat simulations. In a combat simulation the essence of combat is distilled and specifically formulated as mathematical representations of war and battle.

The methodology to distill this essence is one of systematic study, where assumptions are made until a mathematical relationship is established, and then an iterative process of removing assumptions and rewriting the relationships begins. This process continues until time, money, or the ability to replace assumptions with data prevent the process from continuing.

These representations are then written into computer programs which allow modern man to simulate war or battle, make changes to the model, re-run the simulation, and

observe and study the results. All these steps aid mans pursuit of knowledge and the understanding of the phenomenon of Clausewitz' "remarkable trinity."

There are many types of models and also many uses. One common feature, though, is their paucity of human factor representations. More realistic models would provide more accurate results, and hence, better information for the various decision makers that rely on models for input to their decision making process.

However, accomplishing this goal of realistic models requires detailed understanding of combat simulations and the significant human factors that affect combat. Additionally, the representations of the salient human factors must be based upon quantitative data that allow the modeler to forego human factor assumptions and construct a mathematical relationship. Combining these representations of human factors is not a simple task and requires much effort. The inherent limitations of the models and the representations of the human factors must be considered and understood. Once all of this is done, incorporating human factors into today's combat models will result in tommorrow's realistic models.

II. HUMAN FACTORS

A. INTRODUCTION

The term, human factors, means many things to many people. To the engineer interested in designing a man-machine system, human factors may mean the average reach of a person, the best place to position a computer display, or the effects of lighting on the ability of a person to read written information (Bailey,1982). To a psychologist, human factors may suggest the person's intelligence or education, his personality, or his ability to adjust to new circumstances (Braun,1979). A sociologist may consider the extent of the person's integration of cultural norms, his ability to assume a role in a given situation, or the influence of group expectations upon the individual's behavior (Berger,1975). But what should human factors mean to the combat modeler?

B. DEFINING HUMAN FACTORS - AN HISTORICAL APPROACH

Holmes (pg.,74) quotes S.A. Stouffer, who performed a rigorous survey study of WW II, as saying that combat is the end toward which all the manifold activities of the Army are oriented, however indirectly, and he also quotes (pg.,135) Ardant du Picq who called battle the final objective of armies. To define human factors as they pertain to combat modelers, historical data will be used to

examine the soldier in battle. For greater generality, the focus will be on "common" soldiers in battle, while the more singular examples of "great men" in history will be excluded.

Before beginning, some advantages and disadvantages of the historical approach should be discussed. One disadvantage, particularly about events that are very old, is the completeness of the data, or the lack thereof. While this is not as much of a concern for recent events, where newspapers and television have recorded, literally, pounds of data, this is a potential shortcoming of ancient history. In addition, since it is battle that will be studied, the stories almost always are told by those that lived. This may not be a representative sample.

However, since war is not conducted as an experiment to observe the soldier, historical studies are valuable in peacetime by supplying evidence otherwise not available (Kellet,pg.,11). Certainly no experimental situation can come close to approximating the realities of a battle, so historical data are necessary. Jessup (pg.,6) states that

> ...history as the study of the past is the only laboratory most social scientists have since they cannot, like physical scientists, often set up controlled experiments. They must gather their data from a study of what has happened in given situations in the past, and consequently they must use history.

Another disadvantage in the historical approach is that history is necessarily told by a historian. There may be bias in the selection of the facts available and their

interpretation. There is always a possibility that an historian may exclude certain facts that go against an hypothesis. Also, some facts may suggest different conclusions when examined in conjunction with other different sets of facts. Additionally, the meaning of these facts comes from the historians mindset which is a product of culture and life experiences. A marxist may understand an event as a result of the struggle of classes, while an American versed in political science may interpret it as a power struggle between political bases motivated by the quest for profits.

It is true that one historian is necessarily selective (Carr,pg.,40). The sheer number of facts available about recent history requires that many will not be included, while possibly all of the limited ancient historical facts may fully be considered. However, Jessup (pg.,7) asserts that in the pursuit of truth, modern historians share with scientists the spirit of critical enquiry and utilize scientific procedures and methods to gather reliable data. Similarly, historical works that are blatantly biased or grossly incorrect probably never survive the scrutiny of the collective historical research community.

Finally, some may argue that history has a limited value because today is nothing like yesterday. While this is true in a strictly philosophical sense, it goes against reality. Carr (pg.,85) agrees that history never truly

(emphasis added) repeats itself, but that to assert men learn nothing from history is contradicted by a multitude of observable facts. Similarly, though talking specifically about combat operations in Viet Nam, the generality of S.L.A. Marshall's (1969,pg.,11) statements ring true:

> I am well aware that the average American who has not been to Viet Nam believes that the war there has nothing in common with the North Koreans and Communist Chinese, against the Japanese in World War II, or the Germans in 1918. The military analyst who has worked all these fields is far more impressed by the identicalness of features, the similarity of problems, the grinding repetition of historical incident.

Confident that history is a reliable resource, it does not take very long to conclude that there are, in fact, a small number of human factors in land battles that are significant. It also does not take much reflection to conclude that these factors are universal and assert themselves in situations involving combatants other than soldiers.

Proving this assertion, Holmes, Kellet, and Keegan used extensive historical data, including a review of the earliest written manuscripts to the latest after action reports of the conflict in the Falkland Islands, as well as anecdotes. Based upon these sources, the human factors of war can be divided into two broad areas of influence upon men: before/after the battle and during the battle.

C. BEFORE/AFTER THE BATTLE

The human factors that affect the soldier's behavior and performance, before and after the battle, are wide reaching in scope. Foremost, the influence of the soldier's culture is a strong force in shaping the individual. This basic force will interact with all other forces the individual will encounter. Idealogy, another basic force, also influences the person in many ways.

As a person transitions from civilian life in society to the role of a soldier in the army, the factors of training, unit esprit, and leadership impact upon that person greatly. The new soldier certainly has to deal with a different personal situation: the new surroundings, the separation from loved ones, the fear. If all goes well, the soldier and the unit will have a sense of high morale.

1. Culture

Holmes (pg.,58) asserts that there is a wide measure of agreement among psychiatrists that much of a soldier's behavior in battle is accounted for by events in the soldier's life that occurred long before ever joining the army. Keegan (pg.,49) states that cultural norms reflect deep seated habits and values that are important parts in determining a soldier's behavior. One example of these cultural components is religion.

The significance of religion can be observed today in the war between the Soviet backed Afghans and the

mudjahadeen who believe they are fighting a **jihad**, or "holy war". The recent removal of Soviet troops from Afghanistan may be considered support for the assertion that size and equipment is not all it takes to win a war.

This importance of religion is found throughout the Mideast today in Iran, Palestine and elsewhere. In WW II, the tenacity and fierceness of the Japanese is also attributed to the influence of their religious beliefs (Keegan, pg.,51). And some believe the strength of the fighting Irish, now and in earlier wars, can be understood in terms of the influence of their religious beliefs also (Holmes, pg.,288).

2. Ideology

Tied to the culture of the individual, but distinct enough to consider separately, is ideology. The feelings of patriotism, the perceived righteousness of the cause, or belief and support of the political system, all offer motivation to the soldier (Keegan,pg.,49). Holmes (pg.,276) quotes John Dollard, who completed an extensive study of the Spanish Civil War, as saying that ideology functions <u>before</u> the battle to get the man in; and <u>after</u> battle by blocking thoughts of escape. For many soldiers "... ideological motivations are likely to contribute more to persistence than to élan" (Kellet,pg.,327), and Holmes (pg.,277) notes that a survey in the Pacific (during WW II)

indicated that the higher the man's conviction about America's war aims, the more likely he was to be willing to fight on.

3. Training

Training has many influences. Keegan (pg.,42) believes that training is designed to inculcate group cohesion and tactical and technical expertise. Holmes (pp.,36-56) proposes the same ideas and discusses them at length. Kellet (pg.,324) describes training as a socialization process that is crucial to the soldier's acquisition of reasonable preconceptions about battle and that learning drills, such as "hitting the dirt", are valuable in counteracting and controlling fear.

This notion of drills addresses one of the important facets of training: discipline. As noted, the rote discipline of reaction drills helps reduce fear and instill confidence before battle by increasing the soldier's perception of his competence. He can do the right thing automatically. Drill also instills the habit of obedience (Keegan,pg.,44). Discipline functions to increase the likelihood that a soldier will carry out the tasks assigned to him by imposing sanctions on undesirable behavior, and limiting the soldier's perceived range of behavior choices (Kellet,pg.,325).

4. Unit Esprit

Unit Esprit, or **esprit de corps**, is at the heart of success in action, so believed the distinguished 18th century French theorist, Comte de Guilbert (Keegan,pg.,46). Holmes (pg.,50) echoes this, saying that it can produce formidable battlefield performance. He describes in great detail the effects of the esprit fostered by a unit's past history and achievements, particularly as it is embodied in the organization of the regiment (pp.,307-315). Kellet (pp.,321-322) feels that unit esprit helps to enlarge and canalize the bonds established among individual soldiers sharing a similar environment: their training, the war, etc. Holmes agrees (pg.,293) that the roots of unit esprit lie in the smallest of military groups, but that the "full flowering" occurs at the higher levels.

5. Leadership

The effects of leadership before and after the battle are mainly in its contribution to the soldier's morale and confidence of being in a good unit. Holmes (pg.,341) says that there certainly is a connection between the individual soldier's motivation and confidence in the upper echelons of the army's command structure. A survey of officers with combat experience in Viet Nam (Marashian, 1979) revealed that the respondents overwhelmingly felt that a soldier's faith in leaders directly affected motivation to fight. Their experience was mostly at the

lower levels of battalion and company. Kellet (pg.,327) says of this level that well trained and experienced officers and NCO's confer a sense of protection on their subordinates.

One other important aspect of the influence of the formal leadership is that they have access, or at least the means, to acquire information. Kellet (pg.,326) notes that decision and persuasion are central to leadership and that the formal leadership controls the channels of information which facilitates the ability to determine a course of action and to convince others of its validity. Leadership during battle, however, is quite different.

D. DURING THE BATTLE

The human factors described above are important to consider when trying to understand the soldier and his behavior in battle, even though their greatest influence is before and after battle. Perhaps surprisingly, Holmes (pg.,75) asserts that battle is not a frequent occurrence of war, though it is easy to think that it is. He believes (pg.,79), however, that to understand the soldier fully, we must consider the context of the war, the factors described above, and also those of battle, even if battle is such a small, **crucial** part of war.

That battles are crucial cannot be overlooked. Battles cause not only physical damage but they destroy morale. Clausewitz believed that once the enemie's morale is beaten

the war will be won (Howard,pg.,44). This is accomplished by destroying the enemy's will to fight, hopefully at once, but more often little by little, battle by battle.

The human factors described earlier are not enough for a complete understanding. Battle is different than war. Kellet (pg.,319) says that "one of the features of combat is its absorbing immediacy." He continues and says that motivations tend to become strongly situational and that some, such as ideology, are temporarily replaced or recast. The factors to be considered next are those most important during battle: the individual soldier, the primary group, leadership, and the immediate environment.

1. The Environment

The environment is not a part of human nature, but it certainly affects all the other human factors. By environment, the temperature, precipitation, amount of light, and terrain are all included. Some effects of the environment are to reduce morale if the soldier is cold, to slow reactions in extreme heat, to reduce ability to see or hear in rain or fog, and so on. On the other hand, if the conditions are favorable, the effects of environment can be synergistic in their improvement of a soldier's morale and his performance. Certainly, a clear crisp day can be uplifting, while fog and rain favor those occupying a well prepared defensive position that is being assaulted.

2. **Leadership**

Men, particularly in dangerous and high stress situations, desire leadership so that their immediate needs may be met and their anxieties allayed (Kellet,pg.,32). The "Fighter" study of the Korean war concluded that the success or failure of the squad depended upon the leader and what he was doing, noting that many men functioned effectively only when they are in or near the presence of a "stronger" person (Kellet,pg.,15).

In dangerous circumstances, the power of example is the strongest (Kellet,pg.,32). Holmes (pg.,341) asserts that it is a fundamental truth that a military leader will not succeed in battle unless prepared to lead from the front. He goes on to show the unfortunate inherent mortality of leaders, particularly at the lower levels. He concludes that

> ...in the last analysis it is the determined and charismatic leadership, and the selflessness and dedication that it represents, that helps to pull men through the rigours (sic) of battle....

3. **The Primary Group**

Holmes (pg.,291) believes that the key to what makes men fight is found in the small group and the bonds that link men together. Kellet (pg.,320) thinks that in combat, the small group sets standards of behavior largely in terms of two primary goals: individual and group survival, and task accomplishment, with the group survival probably being the strongest. He continues, saying that the

standards are enforced by social pressure and that

> ...most soldiers are unwilling to take extraordinary risks, but their self esteem and their membership in the group require that their actions will not be judged unworthy by their fellows.

Keegan (pg.,52) quotes S.L.A. Marshall as saying that men are unwilling to appear cowards in the eyes of their comrades and that "personal honor is the one thing valued more than life by the majority of men." Marshall (1947,pg.,43) also said that all fighting men are the same, that they are sustained by their fellows primarily, and their weapons secondarily. Keegan concludes (pg.,321) that there are two things that produce fighting spirit: the small group of comrades that the soldier fights with and the morale of the individual soldier himself.

4. The Individual Soldier

The morale and capability of the individual soldier is related in many ways to all of the factors discussed so far. These interactions are complex and difficult to determine. Toomepuu (pg.,6) concludes that the important and useful determinants of soldier capabilities are the same as those for civilians, namely mental aptitude, educational attainment, literacy, social adjustment and physical health and strength. The author feels that while this may give an estimate as to whether a certain soldier will do better assigned as a mechanic rather than a cook, it does not help to say whether a given infantryman will be a formidable fighter or a lackluster follower.

There are other considerations about the individual that are important. When has he last slept and for how long? Is he hungry or thirsty? Is he well protected from the environment or is soaking wet and chilled to the bone? Is this his first combat experience or the end of his first year? These are not just philanthropical questions.

Many of the answers to these questions will certainly reflect contributions to the soldier's morale, positive or negative. Few people at the mercy of the elements, for example, maintain a pleasant disposition. Besides morale, many of these issues also affect performance (Hockey,1983).

E. HUMAN FACTORS DEFINED

Using history, an extensive review of war and combat has been made to elucidate the significant human factors. These factors were split into two broad categories because human factors can be considered to have their greatest impact either during battle or before/after battle. The factors belonging to the latter include leadership, unit esprit, training, ideology, and culture. The factors important during the battle include the soldier himself, the primary group, leadership, and the environment.

Though leadership is found in both, different aspects were covered and the difference was primarily in the level of the army structure: the difference between leadership

from the upper echelons, and, the leadership from those that are in place or rise to the fore while "in the trenches".

This classification of human factors into two categories helps to simplify the inherent complexities and helps to give some insight. However, the danger of over simplification cannot be ignored. All of the human factors discussed above are involved. Many interact with each other. Some are predominant in certain situations, yet have no effect in others. Even those that may dominate at one time are not guaranteed to dominate again in very similar circumstances.

This is simply a reflection of the nature of man; complex and intricate across many levels. The interactions revolve around mans emotions, the ability to think, and the circumstances of war and battle. Predicting human performance in any situation requires an understanding of the <u>human</u>, the <u>activity</u>, and the <u>context</u> in which it is performed, but, even a good understanding of these elements is not sufficient, for the interaction between them is also critical (Bailey,pp.,16-17). Until all of this is understood, combat modelers must make assumptions that are reasonable and attempt to simplify the problem so that usable mathematical representations can be developed.

III. COMBAT MODELS

A. INTRODUCTION

Combat models used in computer simulations are a small subset of models in general. A model is often defined as a representation of a real system. A system is any set of objects, processes, and the relationships between and among them. A system could be an airplane in flight, including the plane's structure, weight, and the physical laws of aerodynamics; a product distribution company, including the trucks, routes, warehouses, capacities, and demands for the product; or the system could be the armed forces of a country engaged in combat, including a myriad of things ranging from weapons and logistics to communications and human decision making.

A model of a system could be one of various forms that often depend upon the system. One form the model could take is an actual physical reproduction. Wind tunnels and scale reductions of airplanes are used to model the airplane in flight. New designs can be verified without building the aircraft or risking the life of a pilot. This type of model is usually called iconic (Markland,pg.,6).

Another form the model could take is called symbolic or mathematical (Emshoff,pg.,6). In this form, the system is represented by mathematical equations that represent the objects, processes and relationships in the system. The

example above of the product distribution system could be represented as a linear program, a system of first-order simultaneous equations, which can be solved mathematically to optimize certain variables.

Finally, another form the model could take is that of a computer simulation. In this form, the model represents

> ... a (system) in which the elements of the (system) are represented by arithmetic and logical processes that can be executed on a computer to predict the dynamic properties (of the system)... (Emshoff,pg.,10).

A model of the armed forces of a nation engaged in battle can use various kinds of mathematical equations to represent the weapons and their effects, and it may use logical constructs to represent various decision making processes. These equations and constructs are written in a computer language and the program is run on a computer.

A model seldom includes all of the components and interactions of the real system; if it did, it might be just as easy to study the original system! In many cases, <u>all</u> of the processes and interactions of the system are not known or understood, particularly if there are humans or elements of chance involved. "Insignificant" aspects of the system are eliminated and, invariably, "significant"

aspects are abstracted and simplified (Hartman,pg.,1-2).

> Whether a model is a valid representation of the real system depends as much on the intended use of the model as well as on the structure of the model itself. (Hartman,pg.,1-2)

Both of these aspects, purpose and structure, must be considered.

B. PURPOSE OF COMBAT MODELS

Combat models are most often computer simulations, and the purpose or use of these models may vary. To understand a model, its purpose must be examined. In the Department of Defense (DOD), the purpose of a model can be grouped into four broad categories, but this does not imply that one model is not used for different purposes at different times. These categories are technical evaluation, force structure analysis, doctrinal analysis, and training (Farmer,pg.,10).

1. Technical Evaluation

Models in this category are often used in the acquisition of new weapon systems. The model will include a representation of the weapon system. Certain parameters of the weapon system, such as probability of kill or mean time between failure, is varied to evaluate tradeoffs between competing design constraints or competing systems. Other models in this category are often called engineering models and are basically concerned with the physical laws

of nature and the weapon system. For example, the flight time of a rocket may be compared against various design weights.

2. Force Structure Analysis

Here, models are used to analyze tradeoffs in unit size, organization, and weapon composition. The unit size could vary from the lowest levels, the squad or crew, all the way to corps and army. Investigating the organization may look at including a new weapon system in the current organization or establishing a separate organization altogether. Also weapon composition could look at the tradeoffs involved with more of one system and less of another system.

3. Doctrinal Analysis

This category includes various sub-topics such as tactical or strategic doctrine development, capability analysis, and requirements analysis. In doctrinal developments, the manner in which a unit employs weapons or maneuvers may be varied. At a tactical level, for example, an anti-aircraft weapon system may intentionally not be used at maximum range but rather employed at a range that insures visual identification of the aircraft first. The effects of this doctrine could be evaluated in terms of friendly and enemy aircraft losses and friendly ground losses from enemy air strikes.

Capability analyses will use real world data such as current doctrine, force levels, readiness, and resupply constraints with different possible scenarios such as a one-front war, and then a two-front war to assess the ability of present forces to meet the threat. The focus here is on current ability to meet hypothetical threats.

Requirements analysis is similar to force structure analysis. However, a given task and threat is assumed, such as deploying to a specific area in two days to stop an invasion by an infantry division. The model will work within the given constraints to determine the required forces needed. Current forces are compared to the forces required by the model and shortcomings can be expressed as new requirements.

4. Training Models

Models to teach and train are used in many ways. Many of these models are not computer simulations, but many new ones are (Joint Analysis Directorate, 1986). They may be found in a command post exercise where decisions by the commanders are fed into the model and the model generates the results of those decisions using some simulated battle. Likewise, a model could be used as a driver for a larger exercise, helping to produce logistical requirements or difficulties. The size and scope, as well as the level of these models, can vary tremendously.

In summary then, some models may be used at different times for different purposes, but they are usually built with a single purpose in mind. Besides purpose, combat models can be differentiated by their structure. Not all models will fit neatly into any categorization, but the following is comprehensive enough to highlight the major differences.

C. THE STRUCTURE OF COMBAT MODELS

The structure of a combat model is usually quite complex. Additionally, a given model may incorporate a number of distinct features that a classification scheme is bound to consider as exclusive or opposite. Examples will be noted later. A complete and very thorough taxonomy of combat models, specifically for "warfare simulations", can be found at Anderson et. al. They propose three functional areas as the key to making a taxonomy: purpose, construction, and qualities. Purpose has been discussed above.

While the Anderson taxonomy is too detailed to be considered in its entirety here, the significant differences of a model's structure, that is, its construction and its qualities, have been combined and will be discussed. These significant differences focus on the manner in which the model treats time and probability, the level of aggregation, the scope, the processes represented, and the aspects of the environment considered.

1. Treatment of Time

A model usually treats time in one of two ways: dynamically or statically. In a static time treatment, time is not considered explicitly. There are no equations that have a time variable. On the other hand, if the model is dynamic, it has an explicit representation of the passage of time and it has equations that have a time variable (Anderson,pg.,10). If time is considered at single instants as required in the model, or at a specified interval, the model is also called discrete. If the model represents time as a continuously changing variable, and other variables can change at any time, the model is called continuous (Hartman,pg.,1-5).

2. Treatment of Probability

A model is often classified as stochastic or deterministic. Deterministic models do not invoke any random numbers to pick a value from a distribution of values for a variable. It may use variables that have values thought of as having a distribution, but a single point estimate is used. A deterministic model is given the required inputs, the equations in the model are solved, and the answers are given. A stochastic model, on the other hand, explicitly represents the probabilistic nature of certain events or processes and is fashioned accordingly. Most often this is done using Monte Carlo methods.

3. Aggregation

Aggregation reflects the level of detail in a model. If the model explicitly considers individual weapon systems, such as a tank or rifle, then the model is said to have a high resolution. If the model considers as the smallest entity, a combination of lesser elements, such as considering a company as a force, but not considering the individual weapons that are found in that company, then the model is called aggregated. The level of aggregation, indicated by the smallest entity represented, depends upon the model and can vary within the model as well.

4. Scope

The scope of a model refers to the level of the highest elements engaged in the model, the geographical area, types of forces, and types of weapons. In land combat models, the levels mirror the levels of the current force structure from squad to theater. In fact, the model is often referred to by its level: for example, "a division level model". The geographical area can range from a few square kilometers to a world-wide conflict. The types of forces represented could be those of a single service, combined arms operation, joint operations, or the model may focus on a single component such as artillery or submarines.

In addition, the "sidededness", or way the model treats the opposing forces actions and capabilities, could

be considered here (Anderson,pg.,A-13). The weapons in the model are related to the forces represented, but often the model will exclude certain weapons such as nuclear, biological, and chemical weapons.

5. Processes

The processes in a model affect the entities. The entities are the objects of the system represented by the model, whether they be high resolution or highly aggregated. Attrition, target acquisition, communications, and movement are examples of processes. Models include different processes, and there are different methods for mathematically representing those processes (Anderson, pg.,8). Attrition, for example, can be represented by various kinds of Lanchesterian equations (Farmer,pg.,23) (Institute for Defense Analysis,1975), a shot-by-shot analysis (Farmer,pg.,20), or, the method of firepower scores (Farmer,pg.,58) (Stockfish,1975). Often the method used to represent the process is determined by the level of aggregation in the model.

6. Environment

The environment in a model includes the terrain, foliage, weather, temperature,light of day or darkness of night, and other details such as cities or bodies of water. Most newer models have very sophisticated and complete terrain representations. These representations are used, for example, to compute line of sight from firer to target

or target visibility, and mobility of vehicles. The representation of other parts of the environment will vary from model to model, and the detail of those representations also varies.

D. SUMMARY

Major differences between models allow a categorization scheme to be proposed. These main differences are found in the model's purpose and in its construction. No taxonomy, however, can be simple and complete at the same time. There are many models used by the DOD today. The Joint Chiefs of Staff publishes a catalog of models used by the DOD, and the 1986 edition describes over 600 of them (Joint Analysis Directorate,1986).

While the description and comparison of combat models is not always very simple, a few generalizations can be noted. First, many models may include facets of the categories above in different parts of the same model. A brigade level model may consider individual tanks using a stochastic shot-by-shot analysis of the tank engagements, but aggregate field artillery tubes to the battery level and use a deterministic force-on-force evaluation of artillery and counter-artillery fire. Then the model is used at one time to assess tactics of new weapon system (Gallagher,1988), and at another time to assess its own

value as a model of training exercises (Ingber,1989). One such model is JANUS. (Joint Analysis Directorate, pg.,J-31).

Another generalization within the possibilities and exceptions noted is that large forces, or high level models, tend to be highly aggregated and use deterministic equations, while lower levels, or small forces, have high resolution (little or no aggregation) and use stochastic methods. In fact, many models that fit into the latter category are often used to "feed" data to models in the former and were built for that purpose.

IV. INCORPORATING HUMAN FACTORS INTO COMBAT MODELS

A. INTRODUCTION

If human factors are to be incorporated into combat models, then both must be considered. The human factor and its relation to combat must be understood. It must be an important factor that significantly influences combat, and there must be verifiable data to support the modeler as attempts to specify the mathematical representation of this factor and its relation to other variables are made.

Since models are so different and complex, the factor cannot be added simply as an afterthought. A specific model must be chosen, and its inner workings and assumptions must be thoroughly understood, as well as its relationship to other models, if any. The mathematical representations of the processes must be well understood so the factor may be appropriately modeled and incorporated.

This all presupposes that human factors should, indeed, be included. The first step, then, is to insure that this supposition is correct.

B. TO HUMAN FACTOR OR NOT...

The decision to incorporate human factors must be based upon an examination and evaluation of the arguments for and against doing so. This decision will be limited by the ability to incorporate human factors, and the costs to do

so should not exceed the benefits. The costs and benefits, of course, are not measured in simple monetary terms alone. The full range of benefits and opportunity costs should be considered. These considerations and the arguments for and against incorporating human factors into combat models will be examined below.

Some of the reasons for including human factors, or as it is often thought of, including more realism in combat models are the following: more realism in models will provide improved model results and, therefore, better input for the decision makers; as a means of studying war and combat, more realism in models allows a better understanding of those organizations and organizing ideas; and, finally, it is the next logical step in modeling methodology to remove assumptions or insert the "insignificant" aspects ignored earlier, accounting for them explicitly.

Some common arguments against including human factors are as follows. If human factors are included on one side, then they must be included on the other, and the hypothetical net effect in the model is a cancellation-- it is not necessary. Another argument is that the reality of war and combat can not be **truly** simulated, so what good is a little more realism when the model will never come close anyway-- why bother at all. Finally, another argument asserts that human factors are extremely complex, there is

no real understanding of them, nor is there sufficient valid data to use to model the factors-- it can not be done.

1. All Opposed

One counter to the "why bother" is the simple fact that incremental improvements are the foundation of modeling methodology. This is an iterative process (U.S. Army Soldier Support Center Report DABT58-81-C-0139,pg.,21) (Emshoff,pg.,57) (Markland,pg.,7). Surely no modeler would argue that models will ever **truly** simulate combat. That is part of the definition of a model: a representation of reality. Combat models attempt to describe the phenomena of war and battle, they do not try to prescribe some set of rules for conducting war and battle. Thus, one goal in the model is to have as good a representation of reality as possible.

The argument that "it does not matter" requires a little investigation to determine that, while on the surface the argument is appealing, it does not withstand scrutiny (Van Nostrand,pg.,13). First of all, human factors are dependent upon cultural influences. Certainly, many opposing forces will have different cultural origins. If, on the other hand, the cultures are very similar, the organization of the forces are often different. Human

factors are affected by the organization of the forces because this directly influences the organization of the primary groups.

Similar arguments apply to the tactics, doctrine, and leadership of the different sides. The human factors to be included in a model are not simply additive or multiplicative constants that are the same for both sides.

Finally, Miller and Bonder (U.S. Army Research Institute for the Behavioral and Social Sciences Report 571,pg.,6) concluded, after reviewing nine models and 112 combat processes, that

> ...a **general** (emphasis added) improvement in the treatment of human factors in combat models would be likely to have a large and unpredictable effect on simulated battle results.

The final argument against incorporating human factors into combat models, that "it can not be done" has some substance. Meister (pg.,141) says that it is cliche to say that a model is only as good as its data, but the great weakness of models is the lack of appropriate data with which to exercise them. He notes that no one performs research solely to secure data for model purposes. However, the situation is not hopeless.

Van Nostrand (pg.,2) also notes that there is no single source of human performance data that could be accessed directly for modeling purposes, but she does cite

various data sources that could be consulted. The data may have to be screened and judiciously selected, but some does exist.

2. All in Favor

Having considered the arguments against incorporating human factors into combat models, consider the arguments in favor. That to include human factors is the next logical step in the modeling methodology has been discussed. This certainly is a valid reason, and from a purely academic standpoint is reason enough.

Continuing along an academic perspective, the potential for greater knowledge and understanding of war, combat, and organizational perspectives is too great to miss and should be pursued. The application of any knowledge gained in these areas from attempting to incorporate human factors into combat models promises benefits and improvements to current doctrine and organization that would not be purely academic.

If doctrine and organizations are better understood and the military reformed to be more effective, then deterrence would be enhanced by the presentation to enemies of a more formidable force and cost reductions would result from increased efficiency. Likewise, if war erupts because deterrence fails, any increased knowledge of war and combat gained earlier would have a direct influence upon national survival.

Finally, the first argument in favor mentioned above, providing better information for the decision maker, is the most important, with great implications. Many of these decision makers are at the highest levels in the DOD. Their decisions about hardware acquisitions, force structures, and doctrine all impact the way our nation's resources are committed. Anyone familiar with the dollar amounts associated with these decisions and the DOD budget should not find it hard to conceive of large savings from improved decisions made by these decision makers. The savings associated with better decisions regarding our nation's defensive strength and preparedness are difficult to assess, and may only amount to increased confidence that the right decision was made, but the potential benefits from improved decision making can not be ignored.

3. Motion Carried

This somewhat lengthy discussion was not in vain. Before deciding how to do something, the more important question to answer is whether this something need be done at all. The author feels that arguments against incorporating human factors are weak, except for comments on the scarcity of data available right now, and that the range and significance of opportunity costs associated with not incorporating human factors make it imperative that this be attempted.

Confident that human factors should be incorporated into combat models, attention now turns to how to accomplish this. The focus will be on how to pick which human factors to incorporate into which models. Obviously, both will influence and interact with the choice of each other. Ideally, both are considered simultaneously, but for clarity, they will be discussed separately.

C. PICKING THE RIGHT MODEL

The choice of models in which to include human factors will influence the choice of human factors to be included. These limitations are imposed by the model's purpose and structure. The structure will favor or preclude certain factors, as will the purpose.

1. Limitations Imposed by the Structure

The structure is important because it may preclude certain factors from ever being considered. Consider in a model the treatment of time. If the model uses discrete events and the factor has an explicit, continuous time dependence, then including it a may pose a problem. For example, if the human factor being considered is how a soldier maintains a picture of crosshairs on an enemy tank to guide a tube launched anti-tank missile, and this factor varies significantly with time over a few hundred milliseconds, then a model that considers time in discrete intervals of one minute can not consider this factor.

Consider a stochastic model. Human factor representations derived from an expected value or average value possibly may be used readily in a deterministic model that requires only a point estimate, but they can not be included in a stochastic model that requires a known distribution of values from which to randomly select one.

Finally, consider a model that has high resolution. Human factor representations based upon data that were recorded for a company or battalion evaluation, for example, will be difficult to include into a model that explicitly considers individual weapons and crews.

In addition to the structural aspects above, other aspects of the model structure, the scope and environment, must be considered. Obviously, and perhaps most importantly, if the model deals with opposing forces, the equivalent (not equal) factors must be derived and included for the opposing forces. Otherwise, the results of the model may be extremely difficult to understand in relation to what the model does and does not include. Did Red win because it is better, or because that side of the model has more assumptions built in, does not consider the human, and is, therefore, more efficient and likely to win?

On the other hand, if the model's structure accounts for weather, day or night, and other environmental conditions, then the modeler has an opportunity to include those factors which have a dependence on them. In this

case, the structure of the model has offered greater possibilities for the modeler to consider rather than impose limitations.

2. Considering the Model's Purpose

In addition to the model structure, the model's purpose may favor or preclude certain human factors. If the model is used to evaluate tradeoffs based upon the laws of physics, such as weight versus flight time in a technical evaluation or engineering model, then the infusion of human factors may not be required nor desired.

An interesting problem is presented if the model is specifically used to feed data to other models (General Research Corporation,1973). Human factors included in one may eliminate the need in the other. The factors will have been fully accounted for in the first. The possibility of "counting twice" must be guarded against and prevented (U.S. Army Concepts Analysis Agency Report SR-86-34, pg.,3-1). This inter-relationship of models, and specifically which models are included in these kinds of relationships, must be known. Then an evaluation must be made to decide which model should be changed, if any of them will be.

If the model is used for training purposes, then perhaps the modeler has the most freedom. In these circumstances, the human factor representations may not need as strict a tie to quantitative data as in other

models. For example, the vagaries of war may be modeled from historical data, and a commander and his staff in a war game suddenly may be faced with the possible mishaps that accompany the "fog of war". Their simple movement order was "misunderstood" and one of their units is reported crossing the river at the wrong location! What do they do now? The possibilities for valuable training are very great.

In conclusion then, given a model, or once a model is chosen, the modeler must become intimately familiar with both the purpose and structure of the model to determine any limitations to, or opportunities for incorporating human factors. Some models may already include a small measure of human factors, but care must be exercised before accepting even those. Burton and others (Lawrence Livermore Report UCID-21551,unnumbered page in the introduction) noted, after an extensive review of combat models that

> ...several models did incorporate human performance assumptions which were found to be incongruent with real world data about how people behave under various environmental conditions and both physical and cognitive stress.

D. PICKING THE HUMAN FACTOR

The human factors that will be modeled by mathematical representations in a combat model are limited by the validity and availability of the data required to construct these representations. This is so because the need for a

quantitative link to reality is paramount in mathematical modeling to solidly establish the soundness of the model.

This requirement forges the weakest link in the whole chain of incorporating human factors into combat models. Currently, there is some data available for a few human factors such as the effects of heat or sleep loss. For other factors related to specific task performances and small group behaviors, current efforts seem promising in providing the necessary data in the next five to ten years. Unfortunately, there are some factors such as individual decision making in combat that seem as if they will not be quantified for quite some time. And in all of these, the validity of the data might be challenged, because none of it is derived from "an experimental war", the true laboratory setting for combat.

1. What We Have Now

Most of the human factors for which there is some data available now focus on the individual soldier. The notion of sleep loss has been of interest, particularly since the Army has been contemplating continuous operations as the norm in future battles (Van Nostrand,1988) (National Health Research Center Report 86-22,1986) (U.S. Army Research Institute for the Behavioral and Social Sciences Report 505,1981) (U.S. Army Research Institute for the Behavioral and Social Sciences Report 80-4a,1979) (U.S. Army Research Institute for the Behavioral and Social

Sciences Report 386,1979). Some data, such as the minimum required amount of sleep to prevent performance degradation, is still under contention. Not surprisingly, none of the researchers seem to have agreed upon a mathematical formulation for incorporation into models.

The effects of stress and fatigue on the individual have been investigated quite extensively in the laboratory (Hockey,1983) (U.S. Army Research Institute for the Behavioral and Social Sciences Report 79-A14,1979). Methods for simulating combat stress are now being investigated and if successful, the data will probably be more readily accepted (U.S. Army Health Services Command Report 86-003,1986). Some of the stressors examined have been heat, cold, noise, vibration, ambient light levels, and dangerous environments. However, except for a general notion of an inverted " U " shaped curve in performance versus stress (or arousal), there is no consensus among investigators about a specific mathematical formulation.

An individual's performance in heat, specifically when clothed in chemical weapon protective gear (Mission Oriented Protective Posture-MOPP) does, however, seem to have some consensus. At least the data were derived from the somewhat more realistic settings of actual soldiers performing the required tasks of different jobs with and without the MOPP gear, though some jobs such as tank crews were noticeably absent (U.S. Army Material Systems

Analysis Activity Report 313,1981). More recent work intends to address this shortcoming (U.S. Army Health Services Command Report 86-003,pp.,152,203).

Other studies have been done on relatively stable characteristics of the individual such as the influence of culture or national characteristics and education and aptitude on performance. Many of these studies have seldom gone much further than to conclude that there is a statistical significance worthy of attention (U.S. Army Research Institute for the Behavioral and Social Sciences Report 708,1986) (U.S. Army Soldier Support Center Report ACN-64024,1981). Two have proposed some quantification of national characteristics: one mentions Soviet studies (Van Nostrand,pg.,8) and the other draws on extensive historical data analysis (Dupuy,1979).

Perhaps a summary for the data available today is this: there is some data available, there is generally no consensus, and overall, its usefulness for combat modeling is dubious at best. However, this is not cause to cease activity. Incremental improvements are better than none. Meister (pg.,141) states that modelmakers are avid in collecting whatever data are already available. In doing so, emphasis must be placed on carefully screening and comparing the data to insure it is appropriate.

2. **What is Coming**

Some recent developments in the manner of gathering data foster hope for the future. In the laboratory the use of surrogate measures, easily measured parameters that have a known relationship to those parameters under investigation, and the use of computers to conduct the data gathering, is being proposed (Kennedy,1987). For other studies the setting is no longer a sterile laboratory environment. In one case, SIMNET, it is a fairly realistic interactive simulation network and in the others, such as the National Training Center, live exercises are conducted with fairly good simulated weapons effects and non-intrusive recording of data. As stated by Link and Shapiro (pg.,10), the premise is

> ...that human factors effects are most easily and accurately (measured) ... by human involvement in roles as nearly identical to those assumed in actual combat....

The most recent development, SIMNET, is an interactive, distributed simulation network that provides real time graphics of battle scenarios (Radgowski,1989) (Defense Advanced Research Projects Report 6929,1988). Current usage consists of realistic fighting vehicle mock-ups, ground and air, "operated" by real soldiers. When they look outside, they see the "planet SIMNET". Each view is different depending upon the vehicle's "actual" position. Thus, for example, the tank in the middle can see the tanks

to his left and right, while the left most tank sees terrain to his left and his fellow tank on the right.

The soldiers must perform the actual tasks of driving or flying, acquiring targets, loading, firing, communicating with each other, etc. The mock-ups provide noise, simulate the feeling of movement and when a weapon is fired, for example, the computer checks the aim, speed of the vehicle, and other pertinent factors, displays a round going down range, a hit or miss, and any retaliatory shots by the "enemy". The computer can record various parameters for real time analysis or save the data for later analysis.

The potential here is enormous! Very strict testing standards can be imposed to obtain accurate, realistic data on numerous human factors. Various demographic variables can be measured, the soldier's training level and unit morale can be measured or estimated, fatigue or sleep loss could be induced, and then performance in target acquisition, firing times, loading times, or perhaps even tactical decision making, can be recorded and analyzed.

The use of non-intrusive television and audio recordings together with weapons simulated by using lasers (Multiple Integrated Laser Engagement System-- MILES) are being used at the National Training Center (NTC) (Ingber,1989) (Buck,1987) (Furman,1982). A battalion faces a highly trained unit that operates under Soviet tactics.

The action is as real as any exercise can get; certainly better that a laboratory. Here again the potential is great. However, the NTC has had some problems because of its size and the amount of equipment necessary to record all of the action (Government Accounting Office Report NSAID-86-130,1985).

A paper published in 1979 discussed the Small Force Engagement Range-SFER (Link,1979). In the SFER, the focus is on a platoon or two that is ambushed while providing security for a vehicle transporting nuclear weapons. The scenario could be manipulated and various human factors such as the influence of the primary group, leadership, and, perhaps individual decision making, could be linked to psychological variables measured before and after the event, and situational circumstances contrived to occur in the scenario. Unfortunately, an extensive search found nothing more published about the SFER since the original paper.

While the potential of all of these methods is great, it will not be maximized unless there is a structured, coordinated, and adequately funded program to develop and implement the necessary data gathering and analysis efforts specifically for combat models. An ad hoc approach by various, unrelated organizations could result in the same state of affairs that exists with the scant data available today.

3. Off in the Future

Some of the important human factors still are only vaguely understood and experiments are being conducted to verify basic theories. The influences of culture or ideology on behavior (Berger,1975) (Braun,1979), defining and measuring morale or unit esprit (U.S. Army Research Institute for the Behavioral and Social Sciences Report 617), the intricacies of organizational structures (Pennings,1986), and most importantly, the all pervasive, human decision making (Arkes,1986) (Estes,1980) all fall into this category.

Interesting methods to attempt to model human decision making are using artificial intelligence techniques. Artificial intelligence uses unique computer languages and attempts to simulate human decision making, defining hueristics or rules that search codified human knowledge (Rowe,1988).

The RAND Corporation has been working on adapting and extending the artificial intelligence techniques of production rules, scripts, goal-directed search, and pattern recognition (Davis,1984,pg.,iii) (Davis,1982). They have built an automated war game of the strategic and operational levels with modules that represent Red, Blue, and third world country behavior using expert system, rule-based, logic. Experts from various fields were assembled to describe a country's behavior given various

circumstances. These behaviors are captured in if-then logic statements that examine the "environment" and then decide on a behavior choice (Hall,pg.,4). The modules do not program behavior in the sense that the same behavior is always executed, but the behavior is very rich and diverse, depending upon the combination of many factors and occurrences within the wargame.

O'Keefe and Phelps have written recently on the subject of combining artificial intelligence techniques with operations research techniques (Phelps,1986) (O'Keefe,1985). Phelps (pg.,14) feels that

> ... for the efficient solution of complex problems, a combination of approaches is called for: objective models for those parts of the system capable of mathematical description, together with human-style heuristic reasoning for the more complex and behavioral parts.

One of the behavioral parts, human decision making, could be investigated and simulated by the development of expert systems. The rules could account for the various phenomena of cognitive and psychological biases such as framing or recency, and satisficing versus optimality, so important in influencing an individuals ultimate decision.

Certainly progress is being made in these areas, but the possibility for data and usable mathematical formulations in the near future is unlikely. The author feels that much of an individuals thinking, small group behaviors, and other psychological and sociological aspects of combat models must use these techniques to achieve

representation in combat models and the search for "hard data" in these areas might have to be abandoned.

Indeed, artificial intelligence techniques and expert systems should be combined with different types of combat models and sensitivity analyses of the models to these human factors should be conducted. The results of these analyses will guide the refinement and future development of these methods, help to validate this approach to incorporating human factors, improve combat models by adding more realism, and indicate to experimentalists which areas should be given priority for efforts to obtain hard data, if at all possible, in the years ahead.

E. COMBINING THE TWO

Regardless of the specific combat model and human factor to be incorporated within it, certain precautions and constraints must be considered. One usefulness of models is their simplification of reality. If all human factors were incorporated, it may be that the model is realistic but so complex that any attempts by "outside" people to understand it are bewildering, if not impossible. Perhaps even the modelers that made it so complex may find it difficult to explain the model to someone else, find and correct a software glitch, or make minor adjustments to try

novel ideas in the future. Davis (1982,pg.,15) believes this also, and says that

> ... an attempt to treat all ... (human factors) at all times would immediately prove both impossible and undesirable-- it would merely clutter the landscape with noise.

Likewise, models are useful if they can be run numerous times so that different variations of input data or conditions may be tested and the output analyzed. This is the foundation of simulation models. If the model is so complex, causing the input of data or changing of parameters to become extremely tedious, or if the run time of the model on the computer is very long, timely analysis and the model itself is in jeopardy.

Preventing unacceptable complexity and run times requires that caution be exercised when deciding which human factors to incorporate. A decision to include only the most significant human factors as determined by historical analysis and empirical performance degradation data is this author's recommended approach.

Another approach requires a detailed analysis of the model of interest to determine what factors affect the model the most. For example, in the areas of fatigue and sleep loss, including these factors will result in degrading the performance presently modeled. Some general models of this effect, say a flat curve to a breakpoint followed by a negative exponential, would reveal whether

this factor is significant or not with regard to some measure of battle results such as loss ratios.

The author feels that this sensitivity analysis will account for idiosyncracies of various model structures, but that it is not necessarily a reflection of reality. A model's structure may be sensitive to a human factor that is determined to be insignificant by historical or empirical methods. Likewise, human factors judged to be significant by historical and empirical methods may prove to be insignificant in a particular model because of its specific structure formulation. Ideally, both approaches should be used to zero in on the factors to be included.

The constraint against building a totally new model often exists and this requires that the human factor mathematical representations and the ones in the model already, be compatible. Van Nostrand (U.S. Army Concepts Analysis Agency,pg.,1-6) suggests that human factors type computations be performed in a separate logical computer module, and the results of these computations (pergorithms or personnel algorithms) be represented by the addition of a single variable to the set of variables that describe the entities in the model. The notion of post processing and pre-processing of data is also mentioned as an alternative to changing the model itself (Van Nostrand,pg.,8).

F. SUMMARY

Attempts to incorporate human factors into combat models must be made. Obviously, this is not a simple task of just combining two things together. Detailed understanding of the model's purpose and structure is required, as well as a determination of the significant human factors in combat and in the model.

These factors, whenever possible, must have data to support the mathematical representations, and these representations must be compatible with the model. The factors involving decision making and other psychological and sociological aspects of man should be modeled with artificial intelligence techniques until hard data is obtained. The changed model must still be usable in terms of its complexity and run time.

It is the combination of this process of incorporating human factors into combat models and analyzing the results of realistic models that will prove the most beneficial to increasing man's understanding of war and battle.

V. CONCLUSION

One of man's endeavors to understand war is through the use of combat models. These models attempt to represent reality and yet still be simple enough to help provide valuable insight into the true nature of war. War is a human venture, and therefore combat models must account for man. Human factors must be incorporated into combat models.

The significant human factors that affect battle should be determined by examining the historical data of war and combat. This examination reveals that human factors fall into two categories based upon when they affect man the most: before/after the battle and during the battle. Culture, ideology, training, unit esprit, and leadership are the human factors strongest before/after the battle. During the battle, they are the environment, leadership, the individual, and the primary group. The last two are the most important.

Before human factors can be incorporated into combat models, the model must be well understood. This includes the model's purpose and its structure. The purpose is one of four types: technical evaluation, force structure analysis, doctrinal analysis, and training. The structure is often quite complex. The structure includes the

treatments of time and probability, the level of aggregation, the scope, the processes, and the environment represented.

Once this has all been done, the two can be combined. Simple to say, hard to do. The model and the human factors must simultaneously be considered, because the selection of one influences the selection of the other. The structure and purpose of the model may limit which human factors can be considered. Analysis of the model's sensitivity to human factor representations will indicate which human factors are significant in that model. Likewise, not all human factors are mathematically representable at the current time. Some human factors, such as decision making, can be included in models using artificial intelligence techniques until the data are obtained, if possible. When the two are combined, the model must still be usable and understandable.

There is much work to be done. The basic thrust is trying to understand man. In some areas the concepts are understood and some data is available. In others, the basic theory is still being debated. Step by step, improvements to combat models in the area of human factors must be made. In the end, the degree and validity of human factor representations in combat models is nothing less than a mirror of the understanding of man himself.

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